Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 JUN 2009	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
A forgotten moment in physiology: The Lovelace Woman in Space Program (1960-1962).	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Ryan K. L., Loeppky J. C., Kilgore Jr. D. E.,	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
United States Army Institute of Surgical Research, JBSA Fort Sam Houston, TX 78234	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**9**	

Adv Physiol Educ 33: 157–164, 2009;
doi:10.1152/advan.00034.2009.

A forgotten moment in physiology: the Lovelace Woman in Space Program (1960–1962)

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Submitted 30 April 2009; accepted in final form 20 June 2009

Ryan KL, Loeppky JA, Kilgore DE Jr. A forgotten moment in physiology: the Lovelace Woman in Space Program (1960–1962). *Adv Physiol Educ* 33: 157–164, 2009; doi:10.1152/advan.00034.2009.—In 1959, Brigadier General Donald Flickinger and Dr. W. Randolph Lovelace II suggested that it would be more practical from an engineering standpoint to send women rather than men into space due to their lower body weights and oxygen requirements. When the Air Force decided not to pursue this project, Dr. Lovelace assumed leadership of the Woman in Space Program and began medical and physiological testing of a series of accomplished women aviators at the Lovelace Medical Clinic in Albuquerque, NM, in 1960. The tests that these women underwent were identical to those used to test the original Mercury astronauts, with the addition of gynecological examinations. Thirteen of the nineteen women tested passed these strenuous physiological exams (for comparison, 18 of 32 men tested passed); a subset of these pilots was further tested on a series of psychological exams that were similar to or, in some instances, more demanding than those given to male Mercury candidates. Despite these promising results, further testing was halted, and the Woman in Space Program was disbanded in 1962. Although the Woman in Space Program received a great deal of publicity at the time, the story of these women was somewhat lost until they were reunited at the 1999 launch of the shuttle Columbia, commanded by Colonel Eileen Collins.

gender differences; history of physiology; space physiology

THE PHILOSOPHER George Santayana famously wrote "Progress, far from consisting of change, depends on retentiveness…Those who cannot remember the past are condemned to repeat it" (16). Ironically, this is a lesson that is forgotten and relearned with each generation. In this article, we will return to a forgotten moment in physiology history, one that was remarkable for its time and place, but one that was subsequently forgotten. Because the data accrued were not published and were therefore lost to the scientific community, the physiological experimentation and testing ultimately were repeated more than a decade later (3, 17), before the first American woman flew in space. This is the story of a remarkable aeromedical physiologist who had a vision that was driven purely by scientific and pragmatic considerations, and how this vision was lost by a combination of personal ambition and the prevailing cultural mores of the time.

Before embarking on this story, it is imperative that the reader (particularly, younger ones) has an appreciation for the legal and cultural status of American women in 1960 as well as for the personalities of the three primary characters who played a role in the genesis and demise of the Lovelace Woman in Space Program. Regarding the former, in 1960, only 25% of women had jobs, and women were not allowed to serve in the military. Furthermore, a woman needed her husband's permission to take out a bank loan or buy property (or even large household goods) (15). In 1963, two seminal events in women's history occurred. First, Betty Friedan published her highly influential book, *The Feminine Mystique*, which questioned the cultural gender roles of the time. Second, Congress passed the Equal Pay Act, making it illegal for employers to pay a woman less than what a man would receive for the same job. By the time the 1964 Civil Rights Act outlawed discrimination in employment based on race and gender, the Woman in Space Program had been cancelled (19).

Three Personalities

W. Randolph ("Randy") Lovelace II, M.D. (1907–1965). W. Randolph ("Randy") Lovelace II (Fig. 1) received his Doctor of Medicine degree from Harvard Medical School in 1934 and subsequently began a surgical fellowship at the Mayo Graduate School of Medicine (14). While there, he studied under Dr. Walter M. Boothby (1880–1953), a physiologist who was already established as a pioneer in aeromedicine. Together with Dr. Arthur H. Bulbulian, these investigators invented the Boothby-Lovelace-Bulbulian (BLB) high-altitude mask to deliver oxygen to pilots; at the time, aircraft cabins were not pressurized, and hypoxia caused pilot errors and accidents (12). For this accomplishment, the research team was recognized with the 1939 Collier Trophy, which recognizes the most significant aviation achievement of the year (1). During World War II, Lovelace served in the Army Air Corps as chief of the Oxygen Branch at the Aero Medical Laboratory at Wright Field in Dayton, OH, continuing his research in aviation medicine. During this time, he personally performed experiments in emergency escape and the use of parachutes at high altitude, culminating in a jump from 40,200 ft in 1943 (for which he was awarded the Distinguished Flying Cross) (18).

After the war, he returned to the Mayo Clinic and his surgical practice. After his two sons died of polio, however, Lovelace returned to Albuquerque, NM, where he joined the Lovelace Clinic, which had been founded by his uncle. To continue his research interests, he established the Lovelace Foundation for Medical Education and Research, which received many government contracts to fund aerospace research throughout the 1950s. With the advent of the space race,

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Fig. 1. W. Randolph Lovelace II, as he appeared at the time of the Woman in Space Program. [From the National Aeronautics and Space Administration (NASA).]

Lovelace was appointed chairman of the National Aeronautics and Space Administration (NASA) Special Advisory Committee on Life Sciences, and he and the staff at the Lovelace Foundation aided in determining both the criteria by which potential astronauts would be tested and the actual selection of the first astronauts (the Mercury 7) (18). By all accounts, Lovelace was a man of energy and vision who got things done by following "The Maverick's Dictum: it is easier to ask for forgiveness than to ask for permission" (1).

Jacqueline "Jackie" Cochran (1906–1980). Just as Lovelace was a pioneer in aeromedical research, Jacqueline ("Jackie") Cochran was the leading woman in American aviation in 1960 (Fig. 2). Born poor as Bessie Lee Pittman, the ambitious Cochran changed her name, reinvented herself, and married Floyd Odlum, who was one of the richest men in America at the time and quite willing to fund her burgeoning aviation career. In the 1930s, she set numerous speed, distance, and altitude records and had won numerous awards. During World War II, she founded and led the Women Airforce Service Pilot (WASP) to fly military aircraft domestically (thus freeing up male pilots for combat service), receiving the Distinguished Service Medal and Distinguished Flying Cross for her efforts. In 1953, she was the first woman to break the sound barrier (with Chuck Yeager flying the chase vehicle).

Unlike her friend Amelia Earhart, Cochran did not help and support her fellow women pilots. Rather, Cochran preferred to compete against men and "…understood the power that a woman gained from being the only female in a room" (19). The following was written of her (1):

> As much as she was a standard-bearer for women in aviation, she was not a strong supporter of individual women. She opened doors to female pilots so that she could be the first to walk through them. As long as she was number one, Cochran cared little about who followed; they had just better stay far enough behind.

In fact, her autobiography was subtitled "The Autobiography of the Greatest Woman Pilot in Aviation History" (4). This personal ambition and competitiveness greatly impacted the Lovelace Woman in Space Program.

Cochran and her husband were politically ambitious and counted among their personal friends such luminaries as Presidents Dwight Eisenhower and Lyndon Baines Johnson, military generals (e.g., Major General H. H. "Hap" Arnold), and the heads of most of the commercial airlines (4). In fact, the award of the 1939 Collier Award to Lovelace and his colleagues was the direct result of Cochran's aggressive lobbying efforts with the rest of the committee (19). Lovelace was personally grateful to Cochran for her efforts, and this began a lifelong professional and personal relationship. While Lovelace served as Cochran's personal physician, Odlum served as the Chairman of the Lovelace Foundation's Board of Directors from 1947 to 1967 (18). Indeed, Lovelace's third daughter was named Jacqueline after her godmother (19). This strong personal relationship would later play a significant role in both the genesis and demise of the Woman in Space Program.

Geraldine "Jerrie" Cobb (1931-present). Geraldine ("Jerrie") Cobb (Fig. 3) began flying at the age of 12 yr and had received both her private and commercial pilot's licenses by the age of 18 yr. By 21 yr, she was delivering military fighters and bombers to foreign Air Forces. In the late 1950s, she set numerous world aviation records for speed, distance, and altitude and had received a number of awards, including being the first woman awarded the Gold Wings of the Fédération Aeronautique Internationale of Paris. She was also one of nine women selected by *Life* magazine as the "100 most important young people in the U.S." in 1959. It was thought by many in the aviation community that Cobb could be the next Jackie Cochran (1, 7, 19).

The Genesis of the Woman in Space Program

In 1957, the Union of Soviet Socialist Republics (USSR) launched Sputnik, the first orbital satellite, and the space race

Fig. 2. Jacqueline Cochran being sworn in as a consultant by NASA administrator James E. Webb. [From NASA.]

Fig. 3. Geraldine ("Jerrie") Cobb beside a Mercury capsule. [From NASA.]

began. Unfortunately, the United States (U.S.) program was running behind, as their rockets consistently exploded on the launch pads. By 1959, Brigadier General Donald Flickinger [of the U.S. Air Force Air Research and Development Command (ARDC) and a member of the NASA Special Advisory Committee on Life Sciences] and his longtime friend and collaborator, Lovelace, were seriously discussing the possibility of sending a woman rather than a man into space. Their proposition was purely pragmatic. First, there would be a reduction in the propulsion fuel required to send the rocket's load into space, as women were lighter and would require less oxygen than men (7). Second, women were known to have fewer heart attacks than men; at this time, it was not known how the stress of microgravity would affect the cardiovascular system. Third, the internal reproductive system of the female was thought to be less susceptible to radiation than that of the male. Finally, there were preliminary data available suggesting that women could outperform men in enduring cramped spaces and withstanding prolonged isolation (5, 19).

By mid-1959, Flickinger had established the Progam Woman in Space Earliest (WISE) at ARDC and had begun to plan how to accomplish testing of women for this space experiment. Lovelace and his colleagues at the Lovelace Clinic had already established a series of rigorous medical and physiological tests for astronaut candidates (9, 10). Male astronaut candidates had undergone these tests, and the first seven astronauts in the Mercury program were introduced to the public on April 9, 1959. Flickinger's plan was to extend testing to women pilots through Program WISE. Coincidentally, Flickinger and Lovelace met Jerrie Cobb in September 1959 at an Air Force Association meeting in Miami Beach, FL, just after they had returned from a meeting of space scientists in Moscow. At this Moscow meeting, they had learned that the Russians were planning to send women into space. In discussions taking place over 2 days, Flickinger and Lovelace asked Cobb to consider becoming the first test subject in Program WISE, and Cobb enthusiastically accepted (17). Additionally, Cobb began to help Flickinger identify potential female candidates for testing by culling through Civilian Aeronautics Authority flight records.

Before her testing could begin, however, Cobb received a letter (dated December 7, 1959) from Flickinger informing her that ARDC had withdrawn support for Project WISE (17). Unfortunately, *Look* magazine had recently put another famous aviator, Betty Skelton, through a series of astronaut tests (with the full cooperation of NASA) as a publicity stunt (1, 19). Additionally, in the fall of 1959, the aviation pioneer, Ruth Nichols, had undergone "some of the astronaut tests" under the auspices of U.S. Air Force physiologists at the Wright Air Development Center, and this information was prematurely released to the public (1, 19). The clear implication from this released information was that the Air Force was interested in promoting a woman astronaut, when this was actually not the case. The combination of these public announcements made Air Force officials extremely nervous, as they were concerned about public reactions to such a program. In a later letter to Lovelace, Flickinger stated the following (17, 19):

> The concensus [sic] of opinion was that there was too little to learn of value to Air Force medical interests, and too big a chance of adverse publicity to warrant continuation of the project. Since there was such great unanimity of opposition I did not see fit to overrule it, and do not plan on reopening the issue with anyone at SAM [School of Aerospace Medicine] or at Air Force Level.

By mid-November 1959, Project WISE was officially cancelled.

Flickinger did not, however, give up on his program. In a letter dated December 20, 1959, he asked Lovelace to take over the program at his private foundation; Lovelace agreed, rechristening it as the Woman in Space Program. Cobb was contacted and reported to the Lovelace Clinic on February 14, 1960 for a week of extensive testing (discussed below), which she passed at a very high level. Cobb was later told that she tested in the top 2% of all individuals, male or female, who took the exam (15). Cobb on her own actively sought further opportunities to press her candidacy as a potential astronaut. Although her request for stress testing at Wright-Patterson Air Force Base was denied, NASA's Lewis Research Center in Cleveland, OH, allowed her to undergo spaceflight simulation testing on the Multi-Axis Space Test Inertia Facility (MASTIF), a huge gyroscope that spun the individual seated in the center in three axes at once (19). The pilot's task was to control the rig while doing 30 revolutions/min on all three axes (1). No less a personage than Alan B. Shepard had hit the "chicken switch" on his first attempt, but Cobb rode the MASTIF for 45 min, earning the respect of the MASTIF handlers (15).

On August 19, 1960, Lovelace announced at the Space and Naval Medicine Congress in Stockholm, Sweden, that Cobb had passed the same physiological and medical exams used to qualify the Mercury 7 astronauts. In doing so, he stated that,

"We are already in a position to say that certain qualities of the female space pilot are preferable to those of her male colleague" (19). Furthermore, in a note accompanying a RESULTS graph, he wrote "There is no question but that women will eventually participate in space flight therefore we must have data on them comparable to what we have obtained on men" (1). Despite his disclaimers that there was no definite space project for women and that the first female space flight was still far off, the Associated Press picked up the story, and Cobb found herself at the center of a media blitz that included a photographic essay in *Life* magazine (19).

Lovelace continued planning to expand the program by examining more female pilots. As always, however, finding funds to support the testing program was an issue. To this point, Cochran had not been involved in the program at all. Upon learning of the plans to test a series of women, Cochran approached her old friend Lovelace in November 1960. Cochran and Odlum agreed to fund the testing (and provide additional generous funding to the Lovelace Clinic), but Odlum made it clear that his wife was to be more than simply the benefactor of the program. In fact, Cochran desired to be both the leader of the program and a candidate for testing, despite the fact that she was over the age limit and had health problems that precluded her candidacy (19). While she did not participate in the testing as a candidate because of these issues, her role in the program was ill defined, and this ambiguity eventually produced issues for the continuation of the program.

Candidate Testing

Like the men's program, the Woman in Space Program would consist of four phases of testing. In the first phase, records and qualifications of potential candidates were screened for health and anthropometric data as well as for flight time experience. In the second phase, candidates would go through a rigorous set of physical examinations and physiological tests at the Lovelace Foundation to determine their physical fitness level and their ability to withstand the presumed physical rigors of space flight. In the third phase, testing would be performed that would simulate the physiological stress of space flight, including the ability to perform under extreme *g*-forces. Finally, psychological evaluations would be performed to determine the candidate's ability to tolerate isolation and other psychological stressors (9, 10). For the men, these latter two phases were performed at the Aero Medical Laboratory at Wright-Patterson Air Force Base. Because his Woman in Space Program was not officially sanctioned and was therefore not officially supported by government facilities, Dr. Lovelace had to arrange for performance of these latter two phases at other facilities using his personal contacts.

Screening phase. In the men's program, candidates were required to be jet pilots who had graduated from a military test pilot school, had at least 1,500 h of flying time, and held a college degree (9, 10) (although the requirement for a college degree was waived in the cases of John Glenn and Scott Carpenter). In 1960, however, there were no women who met these requirements, as women were barred from military test pilot schools, which was the only venue for flying jet aircraft. From September 1960 to August 1961, Jerrie Cobb therefore screened the records of 782 women who held commercial pilot's licenses, looking for women that were healthy, accomplished, and determined (1). Oddly enough, many of the women who were eventually selected for testing had more flying time experience than their male counterparts, because several of them were employed as flight instructors. As examples, Jerrie Cobb had 10,000 h of flight experience, Irene Leverton had 9,000 h, and Jan Dietrich and Bea Trimble Steadman had 8,000 h; in comparison, of the original Mercury 7 astronauts, John Glenn had the most flight experience at a total of 5,100 h (1), and the average of the seven men ultimately selected was $<$3,000 h. In all, 25 invitations were offered on the Lovelace Foundation letterhead, and most of the candidates accepted the invitation. While the invitation emphasized that this was not a NASA project and that the project itself was provisional, the receipt of an invitation from the widely known evaluation center for the male astronaut program elicited in the invitees great excitement for the program and implied that the program might have future stages (19).

Physical examination and physiological testing phase. Physiological testing was performed at the Lovelace Clinic in the spring and summer of 1961, and 19 women (including Cobb) completed the full set of examinations. Unlike the male candidates, the women were not tested in a group and therefore had to rely on only her testing partner (if another woman pilot was being tested at the same time) or herself (if tested alone) to endure the exhausting schedule of testing, which was a test of endurance in itself. This was the same testing schedule as that which the men had undergone, with the addition of a gynecological examination (9, 10); the 1983 movie *The Right Stuff* graphically depicts the rigors of this testing for the men. Within a period of 5 days, the candidates underwent tests that included (but were not limited to) general physical examinations, including complete X-rays; proctoscopic and ophthalmological examinations; electrocardiograms; electroencephalograms (EEG); neurological examinations; blood, gastric, urine and stool specimen analyses; and liver function tests.

There was also an extensive battery of physiological testing. The eminent physiologist Dr. Ulrich C. Luft (1910–1991) had joined the Lovelace Foundation as head of its Physiology Department in 1954 and was in charge of much of this testing (18). The women underwent cycle ergometry tests for the determination of maximal O_2 consumption ($\dot{V}O_{2max}$). Cardiovascular testing included head-up tilt to determine the responses to an orthostatic challenge (Fig. 4) and Valsalva maneuvers (to test for openings between the right and left heart, as it was thought at the time that space flight might make the heart explode). Pulmonary function testing was also performed to determine total lung capacity, vital capacity, maximal breathing capacity, and ventilatory efficiency (via nitrogen clearance). Blood volume and total body water (by the tritium dilution method) determinations were also made. Candidates were flown to Los Alamos National Laboratory for total body radiation count and potassium determination, from which lean body mass and total body fat were derived. Neurological testing included labyrinth function, in which nystagmus was induced by placing cold water into the ear canal, and determination of the conduction velocity of the ulnar nerve using a large coaxial needle electrode for stimulation. In all, each candidate underwent a total of 87 tests (7).

Unfortunately, these data were never published. One of us (J. A. Loeppky) was privileged to have been trained by and

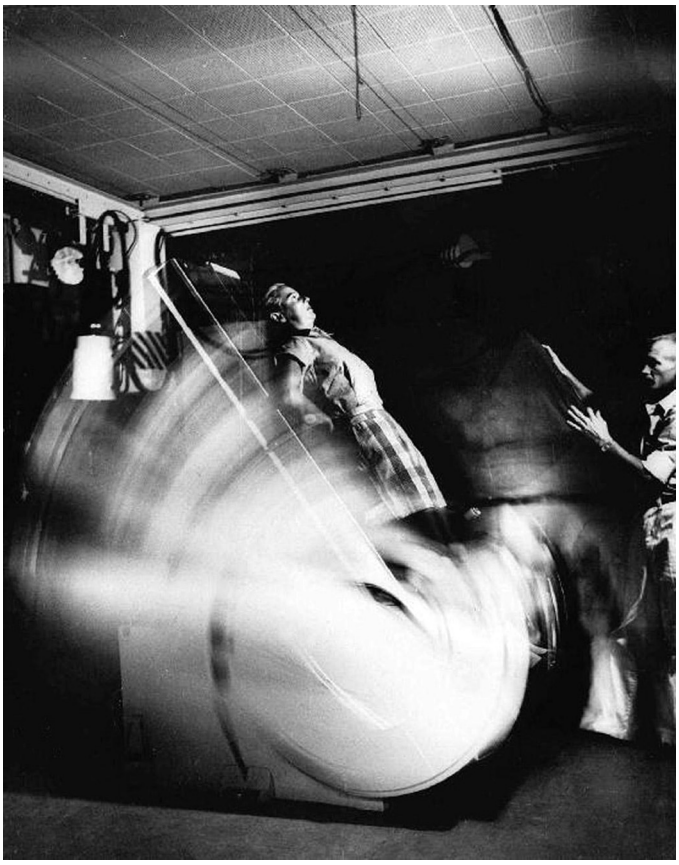

Fig. 4. Jerrie Cobb on tilt table at the Lovelace Foundation in 1960. [From Ref. 13.]

worked with Ulrich Luft and was able to provide the only remaining data on the aerobic capacity obtained during cycle ergometry testing on these women. These data are shown in Table 1. In these 19 women, the average $\dot{V}O_{2max}$ was 26.4 $ml \cdot kg^{-1} \cdot min^{-1}$. For comparison, the average $\dot{V}O_{2max}$ value for 65 male pilots (including Mercury astronaut candidates) tested at a comparable time at the Lovelace Foundation was 32.1 $ml \cdot kg^{-1} \cdot min^{-1}$ (11), a value subsequently confirmed in a much larger group of pilots (8). It is noteworthy that the average $\dot{V}O_{2max}$ value (Table 1) of the top 4 women was not significantly lower than the average of 267 men pilots of similar age from the latter group and that of John Glenn (1). These values fall below the range of more current "textbook values" for nonathletes of the appropriate age range (30–39 yr), which are 30–38 $ml \cdot kg^{-1} \cdot min^{-1}$ for females and 39–48 $ml \cdot kg^{-1} \cdot min^{-1}$ for males (20). These low values for both females and male pilots may reflect the "certified healthy, but sedentary" nature of their profession in the 1960s, the high incidence of smokers in this population, and the mode of testing (cycle ergometry vs. treadmill).

Of the 19 women who underwent the physical and physiological testing, 13 (68%) women passed with "no medical reservations." By comparison, 18 of the 32 men who underwent testing passed, yielding a comparable 56% success rate. Despite this, the only publication that resulted from the testing of the women was that of Betson and Secrest (2), published in 1964 after the demise of the women's program. In that report, there are no data presented but only comments as to the suitability of women as potential astronauts, with emphasis on the potential for the menstrual cycle to alter performance during space flight. In this regard, the authors observed that "the intricacies of matching a temperamental psychophysiologic human and the complicated machine are many and, obviously, both need to be ready at the same time" before concluding that "…it seems doubtful that women will be in demand for space roles in the very near future" (2).

Psychological testing phase. Because of the unofficial nature of the program, there was no ability to follow the physiological testing of the women with psychological examinations at the Wright-Patterson Air Force Base. After her testing at the Lovelace Foundation, Jerrie Cobb herself contacted Dr. Jay T. Shurley at the Oklahoma City Veterans Hospital, a psychiatrist conducting groundbreaking sensory deprivation experiments using a sensory isolation tank. Shurley knew both Randy Lovelace and Don Flickinger and was intrigued by the possibility of studying the psychological impacts of isolation during space flight. Over 3 days, Shurley administered a standard battery of personality and intelligence tests, further EEG and neurological tests, and psychiatric interviews. On the final day, Cobb was immersed in a soundproof isolation tank filled with 34.2°C (skin temperature) water for total sensory deprivation. Based on previous experiments in several hundred subjects, it was thought that 6 h was the absolute limit of tolerance for this experience before the onset of hallucinations. Cobb, however, spent 9 h and 40 min during the experiment, which was terminated by the staff. Subsequently, two other women (Rhea

Table 1. *Age, height, weight, and cardiorespiratory measures during maximal cycle erometer exercise for 19 women tested at the Lovelace Foundation for the Women in Space Program*

	19 Women Pilots (Tested 1960–1961)	Top 4 Women Pilots (Highest $\dot{V}O_{2max}$)	267 Men Pilots (Tested 1958–1971)
Age, yr	32 ± 1	29 ± 3	32 ± 1
Height, cm	165 ± 1	168 ± 3	178 ± 1
Weight, kg	56 ± 2	54 ± 2	76 ± 1
Body mass index, kg/m^2	20.4 ± 0.5	19.0 ± 0.1	24.0 ± 0.2
$\dot{V}O_{2max}$			
l/min	1.45 ± 0.05	1.73 ± 0.05	2.57 ± 0.04
$ml \cdot min^{-1} \cdot kg^{-1}$	26.4 ± 1.1	32.2 ± 0.5	33.9 ± 0.5
Maximal systolic blood pressure, mmHg	166 ± 4	180 ± 8	200 ± 2
Maximal diastolic blood pressure, mmHg	86 ± 2	84 ± 2	89 ± 1
Maximal heart rate, beats/min	180 ± 2	176 ± 7	184 ± 1
$\dot{V}O_{2max}$/heart rate, $ml \cdot min^{-1} \cdot beat^{-1}$	8.1 ± 0.3	9.8 ± 0.4	14.0 ± 0.2

Values are means ± SE. $\dot{V}O_{2max}$, maximal O_2 consumption.

Hurrle and Wally Funk) were also tested, with each spending over 10 h in the sensory isolation tank before termination by the staff (1).

For comparison, the sensory isolation testing experienced by the men at the Wright-Patterson Air Force Base was much different and, in the opinion of Dr. Shurley, inadequate. The men were placed into a soundproof, dark room for 2–3 h. In his memoir, John Glenn recalled that he was seated at a desk in which he found a writing tablet; he wrote poetry in the dark during his 3-h test (6).

Flight simulation phase. Using his informal contacts, Lovelace was able to secure an invitation in May 1961 for Jerrie Cobb to undergo spaceflight simulation testing at the U.S. Naval School of Aviation Medicine in Pensacola, FL. If she were to successfully complete the tests, the remaining candidates would be tested later that summer. The 10 days of tests would include physical training drills and obstacle courses, performance testing in a high-altitude chamber, exposure to high-*g* loads, EEG measurements during jet maneuvers, escape from a submerged cockpit, and performance testing in a slow-rotation room. At the end of testing, Cobb had scored as well as experienced Navy pilots (1), so plans were made to begin testing the remaining 12 women in July 1961.

This testing was not meant to be, however. Although she was aware of the testing performed at the Lovelace Foundation, Jackie Cochran was not informed of the subsequent testing at Pensacola. Upon learning of this testing, Cochran made it known to Lovelace (through a letter written by her husband and Lovelace's benefactor, Floyd Odlum) that she was not happy that she had not played more of a leadership role in the program. In fact, she had also learned that Jerrie Cobb had been recently appointed as a special consultant to NASA. In a letter dated May 31, 1961, Odlum expressed to Lovelace that "Jackie is rather unhappy" that, in her view, Cochran had been detached from the program, with the underlying but unstated issue that Cobb rather than Cochran was the national face of the program. In response, Lovelace sent a conciliatory letter to Cochran and postponed the Pensacola testing of the additional women until mid-September 1961, which would fit into Cochran's schedule. Cochran and Odlum agreed to fund this testing (1).

Because of the informal nature of the arrangement with the Naval School of Aviation Medicine, Lovelace had made sure to keep the testing of the women at Pensacola fairly quiet. In August 1961, Cochran spoke to Robert Pirie, the Deputy Chief of Naval Operations (Air) about her concerns about the Woman in Space Program and followed this with a 2-page memorandum (15, 19). As a result, Admiral Pirie asked NASA whether they had made an official request for the testing of the women. Of course, NASA replied that there was no such official request, and the testing was cancelled, literally as the women were leaving their homes for Pensacola. This was the end of the Woman in Space Program.

Denouement

After the cancellation, the women were dismayed. Some of the women had lost their jobs, as their employers would not release them to be tested (19). Lovelace did not pursue the program further, as he had other space programs to maintain

Fig. 5. Members of the "Mercury 13" gathered to watch Eileen Collins' 1995 launch as the first female pilot of a space shuttle mission. From *left* to *right*: Gene Nora Stumbough Jessen, Wally Funk, Jerrie Cobb, Jerri Sloan Truhill, Sarah Gorelick Ratley, Myrtle ("Kay") Cagle, and Bernice ("B") Steadman. [From NASA.]

and, by his championship of this unauthorized program, had placed himself in a precarious position with NASA (15). Jerrie Cobb assumed the de facto leadership of the women and began extensive lobbying efforts in Washington and with NASA, thereby making the issue of the cancellation of the program highly politicized. Because of this, her NASA consultancy was rescinded in December 1961, despite the simultaneous publication of an article entitled "Lots of Room in Space for Women" in *American Girl* magazine (19). Furthermore, NASA actually sponsored the First Woman's Space Symposium in February 1962, a highly publicized event at which Cobb spoke (19). The issue of the Woman in Space Program was therefore publicly known and debated (1).

Interestingly, one of the 13 women who had passed the physical examinations was Janey Hart, a mother of eight children who happened to be married to a U.S. Senator. Through her congressional contacts, Hart was able to secure a meeting for Cobb and herself with Vice-President Lyndon B. Johnson in March 1962. Although polite to the women during the meeting, Johnson did not support the continuation of the program. Further lobbying by Cobb and Hart resulted in the scheduling of Subcommittee meetings in the U.S. House of Representatives to determine whether women should have the opportunity to be astronauts. While Cobb and Hart made arguments for the Woman in Space program, Cochran appeared before the committee to express concerns about the limitations of the current program and the need for a new, larger program in which, presumably, her experience as a leader would be necessary for success. Finally, representatives from NASA (including John Glenn and Scott Carpenter) testified as to the lack of interest in women in pursuing astronaut training, the lack of women who were qualified, and that the prevailing social order did not accept women in this role (1). In this context, it is of particular interest that many of the 19 women pilots (Table 1) had more hours of flight time and Vo_{2max} values similar to the average of the astronaut candidate pilots and that of John Glenn. After the testimony of Glenn and Carpenter, the hearings were concluded. On June 17, 1963, Valentina Tereshkova of the USSR became the first woman in space, removing the last motivation for pursuing the U.S. Woman in Space Program.

And what of the three major personalities involved in these events? Dr. Lovelace continued to work with NASA on testing the fitness of astronaut candidates until his untimely death in a plane crash in 1965. Jackie Cochran was appointed as a NASA Consultant in June 1963, although further programs for women in space were not pursued. She continued to set records as a test pilot throughout the 1960s, wrote an autobiography in which she assumed the major role in the Woman in Space Program, and died in 1980 (4). Embittered by her experience, Jerrie Cobb continued to lobby until 1965, at which point she began missionary flight operations in the Amazon; in 1980, she was nominated for the Nobel Peace Prize for these efforts. Upon John Glenn's second flight into space, a grass roots "Send Jerrie Into Space" campaign erupted.

More than 30 yr after their testing, 11 of the 13 women who had originally passed the physical tests were united; for some, this was the first time they had met the others. In 1995, the remaining members of the Mercury 13, as they came to be known, gathered to witness Eileen Collins' launch as the pilot of STS-63 (Fig. 5). In 1999, they gathered again as Eileen Collins became the first woman to command a shuttle mission. NASA officials dedicated the launch of this mission (STS-93) to female aviation pioneers.

Perspective

The vision of Lovelace and Flickinger to launch the Woman in Space Program in 1959 was remarkable. The program was launched by investigators intent on furthering science and practical solutions to real problems (e.g., weight and propulsion power requirements) being faced by the burgeoning space program. Their approach was to determine the best individuals for the job, regardless of gender. However, the cultural norms and gender roles of the time made the implementation of such a program practically impossible, even though the women seemed qualified. It was only through the ingenuity of Lovelace and the willingness and enthusiasm of these women that the program was able to advance as far as it did. Indeed, it is amazing that the Woman in Space Program existed at all. Oddly enough, the physiological data collected in the original 1960–1961 testing were never published and were apparently lost. In the 1970s, testing was begun anew to determine whether physiological differences existed between the genders that would influence their responses to space flight (3, 17).

ACKNOWLEDGMENTS

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DISCLAIMER

The views expressed herein are the private views of the authors and are not to be construed as representing those of the Department of Defense or Department of the Army.

REFERENCES

1. **Ackmann M.** *The Mercury 13: the True Story of Thirteen Women and the Dream of Space Flight*. *New* York: Random House, 2003.
2. **Betson JR Jr, Secrest RR.** Prospective women astronauts selection program. *Am J Obstet Gynecol* 88: 421–423, 1964.
3. **Callanen GG.** *Future Space Exploration: an Equal Opportunity Employer*. Santa Monica, CA: RAND, Technical Report AD-A022 287, 1975.
4. **Cochran J, Brinley MB.** *Jackie Cochran: the Autobiography of the Greatest Woman Pilot in Aviation History*. New York: Bantam Books, 1987.
5. **Freni P.** *Space for Women: a History of Women with the Right Stuff*. Santa Ana, CA: Seven Locks, 2002.
6. **Glenn J, Taylor N.** *John Glenn: a Memoir*. New York, NY: Bantam Books, 1999.
7. **Haynesworth L, Toomey D.** *Amelia Earhart's Daughters: the Wild and Glorious Story of American Women Aviators from World War II to the Dawn of the Space Age*. New York: Morrow, 1998.
8. **Loeppky JA, Luft UC.** Work capacity, exercise responses and body composition of professional pilots in relation to age. *Aviat Space Environ Med* 60: 1077–1087, 1989.
9. **Lovelace WR II, Luft UC, Schwichtenberg AH, Nevison TO, Proper R, Roth EM, Woodson GS.** The selection of astronauts including dynamic testing. In: *Proceedings of the First International Symposium on Basic Environmental Problems of Man in Space*, edited by Bjurstedt H. New York: Springer-Verlag, 1965.
10. **Lovelace WR, II, Schwichtenberg AH, Luft UC, Secrest RR.** Selection and maintenance program for astronauts for the national aeronautics and space administration. *Aeromed Acta* 33: 667–684, 1962.
11. **Luft UC, Cardus D, Lim TPK, Anderson EC, Howarth JL.** Physical performance in relation to body size and composition. *Ann NY Acad Sci* 110: 795–808, 1963.
12. **Miller JM.** BLB oxygen mask and aviation. *Mayo Clin Proc* 70: 1020, 1995.

13. **Monash University.** *Hargrave: the Pioneers. Aviation and Aeromodelling–Interdependent Evolutions and Histories. Geraldyn M. "Jerrie" Cobb (1931-)* (online). http://www.ctie.monash.edu.au/hargrave/cobb.html [17 January 2009].
14. **Nelson CW.** Dr. W. Randolph Lovelace II, aviation medicine, and Mayo. *Mayo Clin Proc* 70: 316, 1995.
15. **Nolen S.** *Promised the Moon: the Untold Story of the First Women in the Space Race*. New York: Four Walls Eight Windows, 2002.
16. **Santayana G.** *The Quotations Page. Quotations by Author. George Santana (1863–1952)* (online). From: *The Life of Reason*, vol. 1, 1905. http://www.quotationspage.com/quotes/George_Santayana [17 January 2009].
17. **Shayler DJ, Moule IA.** *Women in Space–Following Valentina*. Chichester, UK: Praxis, 2005.
18. **Spidle W Jr.** *The Lovelace Medical Center: Pioneer in American Health Care*. Albuquerque, NM: University of New Mexico Press, 1987.
19. **Weitekamp MA.** *Right Stuff, Wrong Sex: America's First Women in Space Program*. Baltimore, MD: The Johns Hopkins University Press, 2004.
20. **Wilmore JH, Costill DL.** *Physiology of Sport and Exercise* (2nd ed.). Champaign, IL: Human Kinetics, 1999.